Carbon Isotope Monitoring of Bioremediation of Chlorinated Solvents

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RESEARCH OBJECTIVES

Chlorinated solvents are common groundwater contaminants. They are extremely difficult to remove from groundwater using standard remedial techniques such as pump-and-treat. In situ bioremediation of these compounds represents an attractive alternative. However, because these processes occur underground, they are very difficult to monitor. One promising technique for monitoring subsurface microbial activity is to measure the carbon isotopic compositions of the contaminants and their degradation byproducts. Microbial degradation of organic compounds favors ^{12}C bonds rather than ^{13}C bonds. This causes the products to be depleted in ^{13}C and the substrates to become enriched in ^{13}C. As a result, shifts in the carbon isotope ratios ($\delta^{13}C$ values) can be used to track these processes, provided the magnitude of the isotopic shift is known. The purpose of this research is to quantify the carbon isotope fractionation caused by biodegradation of chlorinated solvents and demonstrate the use of these results for monitoring in situ biodegradation of these compounds.

APPROACH

A combination of laboratory and field studies is being used to study carbon isotope monitoring of bioremediation of chlorinated solvents. Laboratory experiments with organisms known to degrade perchloroethene (PCE) and trichloroethene (TCE) are being conducted. Previous studies have shown that PCE and TCE can be degraded under anaerobic conditions via a process called reductive dechlorination, whereby microorganisms sequentially replace chlorine atoms with hydrogen atoms. In addition, TCE can be aerobically biodegraded directly to CO_2, Cl^- and H_2O. Field monitoring of the $\delta^{13}C$ values of chlorinated solvents is being carried out at several sites, including the TAN site at the Idaho National Engineering and Environmental Laboratory (INEEL), a plume of mixed chlorinated solvents at LBNL and Site 300 at the Lawrence Livermore National Laboratory (LLNL).

ACCOMPLISHMENTS

Our laboratory experiments have demonstrated that reductive dechlorination of TCE causes significant shifts in the $\delta^{13}C$ values isotopic fractionation during each step. This leads to big changes in the $\delta^{13}C$ values of the residual substrates that can be related to the degree of biodegradation that has occurred. The results of this experiment are similar to results obtained for other experiments with reductive dechlorination. The shifts observed during a series of preliminary experiments with aerobic degradation of TCE and its byproducts have found much smaller carbon isotope shifts than these.

The $\delta^{13}C$ values of TCE and its byproducts were measured during a pilot study of enhancing bioremediation of TCE by injecting lactate into a plume at the INEEL. The results were similar to the laboratory results, demonstrating that complete reductive dechlorination of TCE is occurring at the site. At LBNL, the $\delta^{13}C$ values of PCE and TCE are very different in the core of the plume, indicating that they are derived from separate sources. Down-gradient, however, the $\delta^{13}C$ values of both compounds shift to higher values as they disappear, suggesting that natural reductive dechlorination is taking place in the plume.

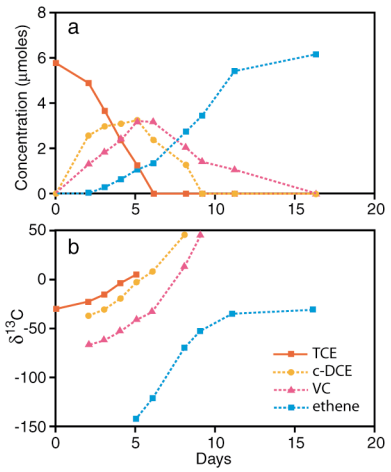

Figure 1. Changes in the concentrations and $\delta^{13}C$ values of TCE and its byproducts during reductive dechlorination by bacteria in laboratory cultures.

SIGNIFICANCE OF FINDINGS

The findings of this work demonstrate the potential for using carbon isotope monitoring to track bioremediation of chlorinated solvents. These results can be used to gain regulatory acceptance for in situ bioremediation of chlorinated compounds.

RELATED PUBLICATIONS

Conrad, M.E., D.J. DePaolo, D.L. Song and E. Neher, Isotopic evidence for groundwater flow and biodegradation of organic solvents at the Test Area North site, INEEL, in Ninth Annual V.M. Goldschmidt Conference, pp. 58-59, LPI Contribution No. 971, Lunar and Planetary Institute, Houston, 1999.

Song, D.L., L. Alvarez-Cohen, M.E. Conrad and K. Sorenson, Monitoring of enhanced in-situ bioremediation of trichloroethylene using stable carbon isotopes, Program and Abstracts for the 4th International Symposium on Subsurface Microbiology, Vail, Colo., 1999.

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